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Evaluating the effect of exchange rate and labor productivity on import penetration of Brazilian manufacturing sectors☆

João Paulo Martin Faleiros [a,*], José Carlos Domingos da Silva [b], Marcos Yamada Nakaguma [c]

[a] *Brazilian Development Bank, Brazil*
[b] *FECAP and PUC-SP, Brazil*
[c] *FEA-USP, Brazil*

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Abstract

In recent years, several economists have argued that the sharp loss of competitiveness of the Brazilian industry was caused by a strong exchange rate appreciation. However, other economists have attributed this loss of competitiveness to the dismal growth of labor productivity in the Brazilian industrial sector. The present paper proposes to estimate the differential impacts of variations in exchange rate and labor productivity on the Brazilian market share of imports measured by the coefficient of import penetration of total demand for manufacturing goods. We start by developing a simple theoretical model to investigate under what conditions the impacts of an exchange rate depreciation and an increase in labor productivity would differ. We test the theoretical implications of the model by means of a GMM panel data analysis focusing on 17 manufacturing sectors in the period between 1996 and 2011. Our results suggest that both variables matter to explain the coefficient of import penetration. Nevertheless, labor productivity has the strongest negative impact on the market share of imported goods, even after controlling for sector fixed-effects.

JEL classification: O14; L6; L16; C23

Keywords: Industrial sector; Imports; Exchange rate; Labor productivity

Resumo

Recentemente, alguns economistas têm apontado um perigoso processo que consiste na perda de competitividade da indústria brasileira causada pela forte apreciação cambial. No entanto, outros economistas têm relacionado esse processo à fraqueza da produtividade industrial brasileira. Neste contexto, o nosso trabalho avalia as diferenças do impacto da taxa de câmbio e da produtividade do trabalho sobre a participação das importações medida aqui pelo coeficiente de penetração da demanda total por bens importados decomposta em setores industriais. Além disso, desenvolvemos um modelo teórico para o entendimento e

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* Corresponding author. Tel.: +55 11 3512 5171.
E-mail addresses: jpfal@bndes.gov.br (J.P.M. Faleiros), zecads@gmail.com (J.C.D. da Silva), nakaguma@usp.br (M.Y. Nakaguma).
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diferenciação de tais impactos. Empiricamente, fazemos uso de uma análise de dados em painel (GMM) considerando 17 setores da indústria transformadora no período entre 1996 e 2011. Nossos resultados sugerem que ambas as variáveis são importantes para explicar o coeficiente de penetração das importações. No entanto, a produtividade do trabalho tem o maior impacto sobre a participação das importações, mesmo quando a avaliação é feita em termos de grupos setoriais.

Palavras-chave: Setor industrial; Importações; Taxa de câmbio; Produtividade do trabalho

1. Introduction

In recent years, the competitiveness of the Brazilian manufacturing sector has become an important policy issue among economists and policy-makers as a consequence of the rapid increase in the share of imported goods in the domestic market since the 90s. In 1996, imports represented only 6.5% of the domestic consumption of manufactured goods. This participation soared during the 2000s, reaching 23.0% in 2008, with a small decline in 2011 to 19.5%. According to several economists, policymakers and industry associations, this large increase in the import penetration coefficient is to be blamed on the excessive appreciation of the exchange rate.

Indeed, the Brazilian currency (real) appreciated in real terms (relative to US dollar) by 60% between 2003 and 2011. According to Armando Monteiro Neto, president of National Confederation of Industries (CNI), the appreciation of the exchange rate affects the competitiveness of the Brazilian manufacturing sector not only abroad, but also in the domestic market. Furthermore, more than 50% of all industrial segments in 2009 faced import competition (Monteiro, 2010). CANO (2012) as well as Bresser-Pereira and Marconi (2010) also emphasize this aspect, suggesting that the level of the exchange rate is the main factor behind the loss of competitiveness of the manufacturing sector during the last decade, and warn that it could lead eventually to a process of deindustrialization.

There is little doubt that exchange rate has an important impact on the level of competitiveness of Brazilian manufactured goods. According to Broz and Frieden (2006) a real appreciation of exchange rate increases the purchasing power of local residents by lowering the relative price of foreign tradable goods. These authors also emphasize that there is a trade-off between competitiveness and purchasing power and that the exchange rate plays a crucial role on the determination of the equilibrium.

However, it is important to point out that, in spite of its importance, the exchange rate is not the only factor that explains the loss of competitiveness of Brazilian manufactured goods. Naturally, productivity is also a key determinant of the evolution over time of the competitiveness of the domestic industry. Bonelli and Pinheiro (2012) listed direct and indirect factors related to productivity that have limited the competitiveness of the Brazilian manufacturing industry. For instance, the quality of infrastructure, the investments in R&D, absorption of foreign technology, labor cost and the educational level. As consequence, in terms of domestic factors, exchange rate is not the only key factor to explain the increase of import penetration, but productivity is also a crucial element. It is, therefore, important to examine which factor that has a larger impact in determining the share of imported goods in the total demand for manufactured goods.

This article evaluates the broad effect of exchange rate and productivity on the recent dynamic of import penetration in the Brazilian demand for goods in the manufacturing sectors. Moreover, we investigate which factor has the greatest impact. At first sight, it is not clear why the impact of exchange rate and productivity on import penetration would differ. We, thus, propose a simple micro-founded model to examine under which specific conditions productivity (as measured by the ratio between industrial production and number of workers) would lead to a larger increase in import participation on domestic market when compared to an exchange rate depreciation. We show that the crucial factor that generates this difference is the participation of foreign inputs in the domestic production. This theoretical result is in line with the argument put forward by Lisboa and Pessoa (2013) that devaluations may protect national industry, but, at the same time, raise the costs of foreign inputs.

To investigate whether this predicted difference in impacts is relevant empirically we make use of panel data regressions for 17 manufacturing Brazilian sector covering the period between 1996 and 2011. Since there may exist simultaneity between labor productivity, exchange rate and import penetration leading to biased estimators, we use a GMM panel data methodology based on Arellano and Bond (1991). Specifically, this method takes the first differences of the variables to eliminate unobserved sector-specific effects and use lagged instruments to correct for simultaneity.

However, as pointed in several works, the use of lagged instruments in the first-difference equation may lead to a weak instruments problem, resulting in large finite-sample biases. To circumvent this problem, we also apply the system GMM panel estimation proposed by Arellano and Bover (1995) and Blundell and Bond (1998).

Our empirical findings confirm that the impact of labor productivity on import penetration is superior to exchange rate. This provides some evidence against the general argument that exchange rate is the key factor behind the massive increase in the share of imported goods in the domestic market between 1996 and 2011. Furthermore, we also test whether our result is holds for two specific groups of sectors that constitute our data: intermediate and capital goods. We show that the impact of exchange rate on these groups is not statistically significant whereas labor productivity coefficient is still negative and significant. This result is mostly due to the higher participation of foreign inputs in the domestic production of intermediate and capital goods sectors. According to our findings, a higher level of imported input ratio in a sector implies that exchange rate impact is less sensitive to import penetration.

Overall, these results support that fact that exchange rate is not crucial for explaining the increase of imports participation on the domestic demand for intermediate and capital goods. This last aspect is important in terms of policy given that devaluation of Brazilian currency may not be effective to increase the market share of local intermediate and capital goods on the domestic market.

The rest of the paper is organized as follow. Section 2 presents some stylized facts about the relationship between import penetration and labor productivity and real exchange rate. Section 3 presents the micro-funded model that supports the theoretical view about the importance of productivity over exchange rate. Sections 4 and 5 present, respectively, the empirical model and results. Finally Section 6 concludes this article.

2. Stylized facts: exchange rate, productivity and import penetration

The recent process of rapid increase in imports of manufacturing goods became a relevant issue in the Brazilian economic debate and many economists and policy-makers have claimed that the exchange rate is crucial in explaining it. There are two main reasons for that. First, economic theory predicts that the relationship between import penetration, measured by the share of imports over the manufacturing apparent consumption, and exchange rate is negative. Indeed, there is evidence that Brazilian imports react positively when the home currency appreciates against major foreign currencies. Second, in recent years, the Brazilian real exchange rate experienced a sharp and rapid appreciation process.

However, in spite of the fact that these arguments gained importance in the national policy debate, there are some aspects of the problem that remain unclear. In particular, little is known about the elasticity of the import penetration to variations in the exchange rate at the sector level.

A preliminary and basic test of this relationship shows that the correlation is negative, as expected, but very small. Fig. 1(a) presents the relationship between the log difference of the share of imports in the domestic market (measured by import penetration coefficient calculated at constant prices) and the log difference of sectorial exchange rate[1] for 17 manufacturing sectors, during the period between 1997 and 2011. Note that the linear relationship is weak and the correlation coefficient is only −0.06. This characteristic is mainly a consequence of the low correlation in the group of intermediate and capital goods sectors. Fig. 1(c) shows that in these sectors the relationship between the two variables is very close to zero, whereas in the sector of consumption good industries, as shown in Fig. 1(b), the relationship is stronger and the correlation coefficient is −0.21.

At the very least, these stylized facts put in check the effectiveness of devaluation policies to protect the national manufacturing industry. The exchange rate appears to be somewhat relevant in reducing the import penetration in the consumer goods sector. However, the same is not true in the case of intermediate and capital goods sector. If the import penetration coefficient of intermediate and capital goods sectors is indeed inelastic to the exchange rate, then currency devaluations elevate input costs and make new investments more expensive.

According to Lisboa and Pessoa (2013), the effect of the exchange rate is ambiguous. Devaluations may protect the national industry, but, at the same time, raise the costs of imported inputs. Because of this ambiguity, Broz and Frieden (2006) pointed out that there is no clear economic policy that could determine one appropriate level of exchange rate.

[1] The sectorial exchange rate is calculated here from the real exchange rate of the Brazilian currency relative to the trading partners for 17 industry sector, measured in terms of consumer prices, weighted by the share of imports of the trading partner in the total value of imports. For more information about the construction of sectorial exchange and other variables, see Section 5.

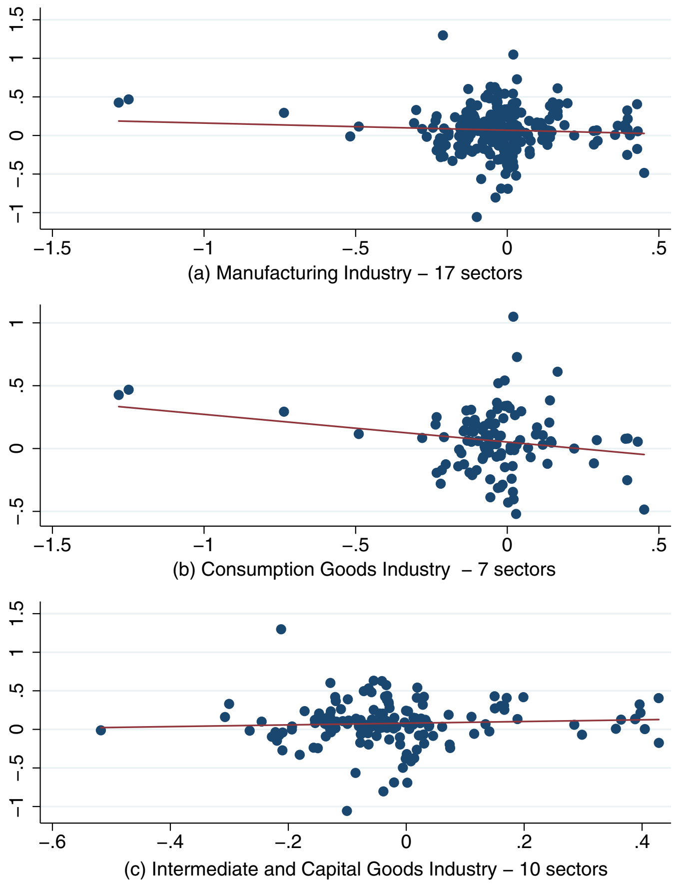

Fig. 1. Dispersion between the log difference of the of the import coefficient (vertical axis) and the log difference of sectorial exchange rate (horizontal axis) for 17 manufacturing sectors between 1997 and 2011.

Thus, it is possible that the use of manufactured imported goods as input by the national industry decreases the sensitivity of import penetration to the exchange rate. In fact, intermediate and capital goods sectors are, in general, more dependent on imported inputs than the consumption goods sectors. According to the databases of input–output matrix estimated by different authors for the period between 2000 and 2009 (Freitas et al., 2012; Guilhoto and Sesso Filho, 2010; Martinez, 2015), the sectors present in these groups has, on average, a participation of around 16% of imported inputs on total inputs demanded in the final production against a percentage of 8% in the consumption goods sectors.

Several economists, on the other hand, have attributed the recent raise of import penetration to the performance of labor productivity in recent years (Bonelli and Pessoa, 2010; Ferreira and Fragelli, 2011). According to Lisboa and Pessoa (2013), while certain sectors in the decade of 2000 were favored by labor productivity gains, e.g. agriculture, most of the manufacturing industry sectors showed a poor performance. Using data from IBGE manufacturing survey (PIM-IBGE), between the years of 2003 and 2011, a period of intense appreciation of the real exchange rate, the industry labor productivity increased only 21%. In particular, labor productivity performance in intermediate and capital goods sector presented a cumulative growth of 18%, while the sectorial exchange rate appreciated 57%.

Whether these segments of economists are correct, we expect that the relationship between import penetration and productivity would be negative and high correlated. Therefore Fig. 2(a) presents the dispersion between the log difference of import penetration and the log difference of labor productivity for all sectors highlighted here. In fact, a preliminary analysis of the data in Fig. 2 reveals that the relationship between these variables is strongly negative. The correlation coefficient is −0.57 for the group of 17 sectors. The same occurs with the two groups of sectors as seen by Fig. 2(b) and (c). In the case of intermediate and capital goods sector the correlation coefficient is −0.65 and for consumption good sector its value is −0.40.

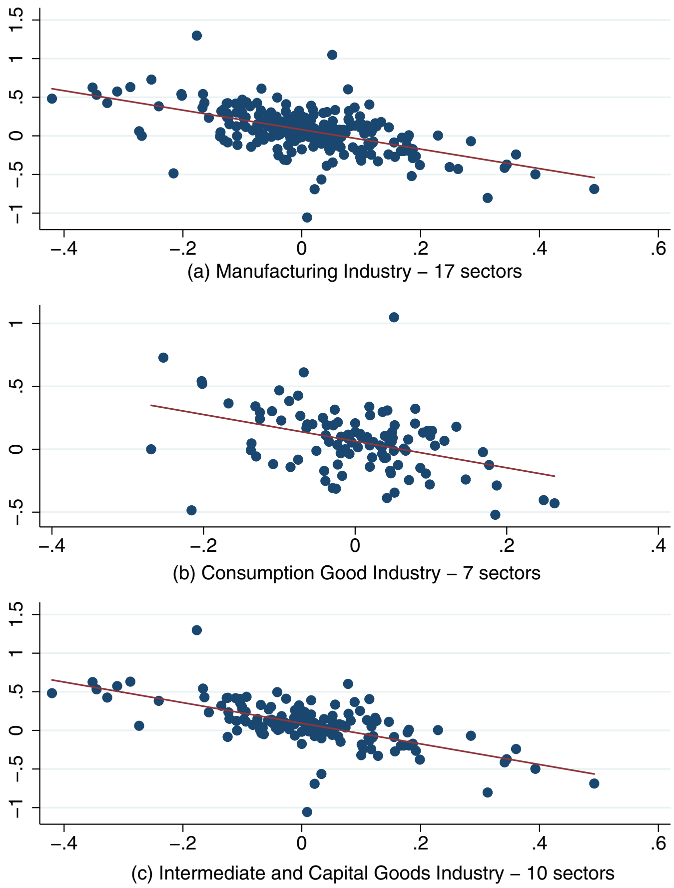

Fig. 2. Dispersion between the log difference of the import coefficient (vertical axis) and the log difference of labor productivity (horizontal axis) for 17 manufacturing sectors between 1997 and 2011.

The role of productivity seems to be more important than exchange rate to explain the rapid process of import penetration. The stylized facts presented here reveal that this difference may be related to the presence of intermediate and capital goods imports. Apparently, this group of sectors does not present any association between import penetration and exchange rate. As a consequence it weakens the relationship for the whole manufacturing sector. We have the impression that the absence of association in this specific group may be explained by deeply structural dependence of foreign inputs in the domestic production when compared to consumption good sectors.

As we will see in the next section, the hypothesis that foreign input dependence weakens exchange rate impact is reasonable when analyzed through a simple micro-funded model. In empirical terms, it is not possible to draw robust conclusions by a simple analysis of correlation. The reverse causality between variables and unobserved sectorial and time effects may be a problem. Furthermore, import penetration may also depend on other important factors as we could see in the theoretical model. Thus, all theses aspects demand different econometric treatments.

3. Theoretical model

This section proposes a simple theoretical model in order motivate the main propositions to be tested in this paper. Throughout this section, we make a number of simplifying (functional form) assumptions in order to keep the analysis tractable. We acknowledge that these assumptions limit in important ways the generality of our theoretical results. However, the model also leads to interesting insights about the relationship among certain key variables that are both testable and have important policy implications.

3.1. Benchmark model

Suppose that there are two countries, a domestic and a foreign country, and that the production function of domestic and foreign firms are given, respectively, by:

$$Y = \alpha L \quad \text{and} \quad Y^* = \alpha^* L^* \tag{1}$$

where Y and Y^* denote the quantities produced in each country and α and α^* represent the labor productivity in the domestic and foreign industries.[2] We assume that the labor supply is inelastic, so that the L and L^* are both exogenous variables. Given the price of the domestic good (in national currency), P, the firm's profit is given by:

$$\pi = P\alpha L - wL \tag{2}$$

where w is the nominal wage. Assuming that there is free entry in the industry, the profit of all active firms should be zero. Therefore, the equilibrium price is given by:

$$P = \frac{w}{\alpha} \tag{3}$$

Note that the term w/α represents the unit labor cost. Similarly, we have that the equilibrium price of the foreign good (in foreign currency) is given by: $P^* = w^*/\alpha^*$.

Next, assume that the domestic demand for both the domestic and foreign goods can be derived based on the choices of a representative consumer with CES utility function given by:

$$U(Q, Q^*) = (Q^\rho + Q^{*\rho})^{1/\rho} \tag{4}$$

where $\rho \leq 1$ is the elasticity of substitution between domestic and foreign goods. The representative consumer has income $R > 0$, which he spends all in consumption and assume, without loss of generality, that $R = 1$, so that his budget constraint is given by:

$$PQ + EP^*Q^* \leq 1 \tag{5}$$

where E is the nominal exchange rate. The consumer chooses Q and Q^* in order to maximize (4) subject to (5). The solution to this problem yields the following relationship between the quantitites consumed in equilibrium of the foreign and domestic goods:

$$\frac{Q^*}{Q} = \left(\frac{w/\alpha}{Ew^*/\alpha^*}\right)^{1/(1-\rho)}, \tag{6}$$

i.e. the participation of imported goods in the domestic market, Q^*/Q, depends on the ratio between the unit labor cost of foreign and domestic firms. Specifically, a reduction in the unit labor cost of the domestic firms, i.e. an improvement in the competitiveness of the national industry, leads to a decrease in the local demand for the foreign good relative to domestic good. Moreover, note that the above equation can be re-expressed as:

$$\log\left(\frac{Q^*}{Q}\right) = \frac{1}{1-\rho}\left[\log\left(\frac{w}{\alpha}\right) - \log(E) - \log\left(\frac{w^*}{\alpha^*}\right)\right] \tag{7}$$

Thus, it follows that a 1% exchange rate depreciation has the same impact on Q^*/Q as an increase of the same magnitude in the labor productivity. Note that this result provides theoretical justification for those who argue that domestic competitiveness can be improved by simply devaluating the exchange rate. But how robust is this result?

3.2. Model with imported inputs

In this subsection, we introduce a single modification to the model discussed above, namely: domestic production now depends on an imported input. According to Lisboa and Pessoa (2013), exchange rate depreciations increase the

[2] Our benchmark model is based on the assumption that labor is the only production input (i.e. there is no role for capital) and that labor productivity is constant. We do so in order to focus on a simple measure of labor productivity (α), which allow us to obtain direct comparative static results on the relationship between productivity and the index of import penetration. This simple type of production function is implicitly assumed in most empirical analyses that propose to measure labor productivity (see, for instance, Bonelli and Fonseca, 1998; Barbosa Filho, 2014).

competitiveness of the domestic industry, but at the same time raise the cost of imported inputs. The model discussed above does not capture such adverse effect of an exchange rate depreciation due to the format assumed for the production function. In order to account for this possible adverse effect, we extend the previous model, now assuming that the production function of domestic firms are given by a Leontief function of the following form:

$$Y = \alpha \cdot \min\left\{L, \frac{1}{\phi}\iota\right\} \quad \text{with} \quad \phi > 0, \tag{8}$$

where ι is the quantity of an imported input used in the domestic production, i.e. we are now assuming that the production of the domestic good requires the use of a certain quantity of a foreign production factor.[3] Note that the optimal production requires that:

$$\iota = \phi L \tag{9}$$

since any other combination of production factors would imply in waste of resources. Note that the larger the value of the parameterϕ, the higher the dependence of the domestic industry on the foreign input. Assuming, without loss of generality, that the price of the imported production factor is equal to one and imposing the optimality condition $\iota = \phi L$, it follows that the profit of domestic firms is given by:

$$\pi = P\alpha L - (w + \phi E)\, L \tag{10}$$

Thus, from the zero profit condition, it follows that the equilibrium price of the domestic good is now given by:

$$P = \frac{w + \phi E}{\alpha} \tag{11}$$

Finally, supposing that both the production structure of the foreign industry and the utility function of the representative consumer remain unchanged, we have that, in equilibrium, the ratio between the demanded quantities of foreign and domestic goods is given by:

$$\frac{Q^*}{Q} = \left(\frac{(w + \phi E)/\alpha}{Ew^*/\alpha^*}\right)^{1/(1-\rho)}, \tag{12}$$

which can be re-expressed as:

$$\log\left(\frac{Q^*}{Q}\right) = \frac{1}{1-\rho}\left[\log\left(\frac{w + \phi E}{\alpha}\right) - \log(E) - \log\left(\frac{w^*}{\alpha^*}\right)\right] \tag{13}$$

Thus, as long as $\phi > 0$, the effect of an increase in labor productivity on the relative demand for the foreign good, Q^*/Q, is larger (in absolute terms) than that of an exchange rate depreciation. Formally, we have that:

$$\frac{\partial \log(Q^*/Q)}{\partial \alpha} = -\frac{1}{1-\rho} \tag{14}$$

and

$$\frac{\partial \log(Q^*/Q)}{\partial E} = -\frac{1}{1-\rho}\left(1 - \frac{\phi}{w + \phi E}\right), \tag{15}$$

where $(1 - (\phi/(w + \phi E))) < 1$. Moreover, it is interesting to note that the larger the dependency of the domestic industry on the foreign input, the lower the impact of an exchange rate depreciation on Q^*/Q, i.e.

$$\frac{\partial \log(Q^*/Q)}{\partial E \partial \phi} = \frac{1}{1-\rho}\frac{w}{(w + \phi E)^2} > 0 \tag{16}$$

[3] The assumption of a Leontief production function is imposed for simplicity, given that it allow us to measure the share of the imported input in the production through a single parameter, ϕ. We acknowledge that this functional form assumption is restrictive in that it rules out the possibility that firms might adjust their use of the imported input in response to an exchange rate depreciation (i.e. price change). Nonetheless, more general types of production function should lead to similar (qualitative) comparative static results as those derived in this subsection.

Thus, it follows that the effectiveness of a policy of currency devaluation in terms of improving the competitiveness of the national industry depends crucially on the production structure of domestic firms and, in particular, on the extent to which they rely on imported inputs. Nonetheless, whether such mechanism is relevant or not in practice is ultimately an empirical question. Thus, in the following sections, we proceed to test whether the theoretical results of our model find any quantitative support in the data.

4. Empirical model

In order to test whether the effects of labor productivity and exchange rate indeed differ, as predicted by the theoretical model, we estimate the elasticities of each variable in Eq. (13). To implement this test empirically, we make modifications in the estimation equation to take into account some specificity of our data. First, our data set consists of annual information for manufacturing sectors in the period 1996–2011. Thus, we introduce both sector and time fixed effects that were not considered by the micro model. Second, disturbances may be possibly autoregressive given that import penetration shocks may have persistent effect over the years. Third, the ratio between the demand of foreign and domestic goods is proxied by the coefficient of import penetration. Finally, due to the impossibility of obtaining foreign wage data for the period considered in the analysis, we omit this variable from the main regression, although it is reasonable to assume that the effect of foreign wages can be adequately captured by the sector and time fixed-effects.

The empirical model, therefore, is given by:

$$\begin{aligned} ip_{it} &= \beta_\alpha \alpha_{it} + \beta_E E_{it} + \beta_w w_{it} + \beta_{\alpha *}\alpha^*_{it} + \gamma_t + (\mu_i + v_{it}) \\ v_{it} &= \delta v_{it-1} + \varepsilon_{it} \quad |\delta| < 1 \quad \varepsilon_{it} \sim i.i.d \end{aligned} \tag{17}$$

where ip_{it} is the log of the coefficient of import penetration in sector i and year t, α_{it} is log of domestic labor productivity, E_{it} is the log of the effective exchange rate, w_{it} is the log of domestic manufacturing wages by sector,α^*_{it} is the log of a proxy for foreign labor productivity and γ_t is time effect. The error components are given by μ_i, a sector specific fixed effect, and v_{it}, an autoregressive shock.

The presence of persistent shocks v_{it} indicate that model (17) may also be described by the following dynamic representation:

$$\begin{aligned} ip_{it} = {} & \pi_1 ip_{it-1} + \pi_2\alpha_{it} + \pi_3\alpha_{it-1} + \pi_4 E_{it} + \pi_5 E_{it-1} + \pi_6 w_{it} + \pi_7 w_{it-1} + \pi_8\alpha^*_{it} + \pi_9\alpha^*_{it-1} + \tilde{\gamma}_t \\ & + \tilde{\mu}_i + \varepsilon_{it} \end{aligned} \tag{18}$$

where $\pi_1 = \delta$, $\pi_2 = \beta_\alpha$, $\pi_3 = -\delta\beta_\alpha$, $\pi_4 = \beta_E$, $\pi_5 = -\delta\beta_E$, $\pi_6 = \beta_w$, $\pi_7 = -\delta\beta_w$, $\pi_8 = \beta_{\alpha *}$, $\pi_9 = -\delta\beta_{\alpha *}$, $\tilde{\gamma}_t = \gamma_t - \delta\gamma_{t-1}$ and $\tilde{\mu}_i = \mu_i(1-\delta)$. The model (18) is an unrestricted model that has a dynamic process that includes an autoregressive component of the import penetration coefficient. This aspect related to the possible existence of reverse causality between variables demand a method of estimation different from ordinary least squared (OLS) and fixed effect (FE). The OLS estimator is an inconsistent estimator given that ip_{it-1} is correlated with the error term because of the presence of the fixed effect. Hence, the estimator tends to be biased upward.

The FE estimator corrects this inconsistency by removing the fixed effect. However, it leads to a non-negligible correlation between the transformed autoregressive component of the dependent variable and the transformed error term. In addition, OLS and FE estimators do not eliminate the problems of inconsistency generated by reverse causality between variables. Notice that the error term may be also correlated with the others variables, for example, shocks in import penetration may contemporaneously influence labor productivity given that both variables were constructed based on the value of industrial production. Furthermore, the effective exchange rate variable E_{it} is calculated by weighing up real exchange rate of Brazilian trade partners and their participation on the total of imports. Needless to say that real wage may be strongly correlated with the labor productivity. Thus, given those aspects, it is possible that the problem of reverse causality may also cause the estimators to be inconsistent.

Thus, we also estimate the regression in Eq. (18) by Arellano and Bond (1991) or first-differenced generalized method of moments (GMM). This method yields consistent estimators for dynamic panel models. It relaxes the hypothesis of strong exogeneity of variables assuming that they are endogenous, i.e., the variables are correlated with the shocks in t and previous shocks. However, they are not correlated to forward shocks. Assuming that, it is possible to use the sequence of lags of the variables in level as instruments, after taking the equation in first difference to eliminate the fixed effect.

Table 1
Manufacturing sector classification.

1	Beverage and food	CG	10	Rubber and plastic	ICG
2	Tobacco	CG	11	Non-metallic minerals	ICG
3	Textile	CG	12	Basic metallurgy	ICG
4	Retail	CG	13	Metal products, except capital goods	ICG
5	Footwear and leather products	CG	14	Capital goods, except 16	ICG
6	Wood	ICG	15	Capital goods – electrical electronics and communication	ICG
7	Paper and printing	CG	16	Capital goods – transportation	ICG
8	Coke, petroleum and alcohol	ICG	17	Furniture	CG
9	Chemicals and related products	ICG			

Note: Classification based on CNAE 1.0; CG – consumption goods sector; ICG – intermediate and capital goods sector.

However, the estimator proposed by Arellano and Bond (1991) may have lagged instruments that is weakly correlated with subsequent first differences variables. This is a case of weak instruments that may cause bias as well as imprecision when explanation variables are very persistent. According to Bond (2002) it happens when the estimated autoregressive coefficient of the dependent variable in first-differenced GMM is near to the within groups coefficient. Blundell and Bond (1998) showed this result by means of simulation exercises that revealed that, when instruments are weak, first-differenced GMM results tend to be biased in the direction of within group estimation.

To solve this problem, Arellano and Bover as well as Blundell and Bond (1998) suggest additional moment conditions by using lagged first-differenced instruments for the equation in levels. The system GMM method, therefore, combines lagged level as instruments in the first-differenced equation with lagged first differences variables as instruments in the level equation. Hence, it is expected that system GMM may cause a dramatic reduction of finite sample bias.

However, our interest lies in the restricted parameters (β_α, β_E, β_w, β_{α^*}, δ). Given the estimated coefficients in (18) and the system of equation originated by the autoregressive shocks process, we estimate the restricted parameters by minimum distance method suggested by Blundell et al. (1996). After obtaining these estimates, we test whether our empirical findings are in concordance with the theoretical model discussed previously.

5. Data

Our data covers the period 1996–2011 and the 17 manufacturing sectors listed in Table 1. The manufacturing data is obtained from Monthly Manufacturing Survey from Brazilian Institute of Statistics and Geography – PIM-IBGE (index of the number of employees associated to production, index of real payroll per worker and manufacturing production index), Annual Manufacturing Survey from Brazilian Institute of Statistics and Geography PIA-IBGE (total number of employees associated to production and manufacturing value of production) and Aliceweb (Brazilian imports and exports by sector). Moreover, besides the information about Brazilian manufacturing sectors, our empirical analysis also requires information on Brazil's foreign trade partners. The sources of trade partner's information are: WDI – World Development Indicators of World Bank Database (consumer index price and exchange rate) as well as Penn World Table (GDP at chained PPPs and the number of employees).

Based on these data sets, we construct four main variables present in our theoretical model: the import penetration coefficient, the real effective exchange rate, the Brazilian labor productivity and an index of foreign productivity. The import penetration coefficient was conventionally constructed as the ratio between imported value and apparent consumption, where the latter variable is defined as the sum of industrial production plus imports minus exports. All measures are expressed in terms of constant prices. The real effective exchange rate is calculated by weighting the real exchange rate (R$ / LCU) of the trading partners in relation to their participation on the total imports of all 17 manufacturing sectors. The construction of real exchange rate is based on consumer prices.[4]

Finally, labor productivity of manufacturing sectors is defined as the ratio between the value of industrial production (output), measured at 2006 constant prices, and the total number of employees (input). This definition of labor productivity is often used in comparative empirical studies, but it must be emphasized that there are other, perhaps more

[4] The real exchange rate is calculated for each trading partner through the ratio of the country's consumer price indexes and the Brazilian consumer price index. The data used in the construction of real effective exchange rate variable is obtained from World Development Indicators and Aliceweb.

precise, measures available. In general, total number of hours worked is broadly accepted as a better input measure mainly because it takes into account technological differences across countries and even sectors over time. However, such information is not easily available for Brazilian manufacturing sectors, especially for the time period considered in this study. Thus, because of lack of available data, we have to rely on using total employment (head count) as a measure of input.

Furthermore, we believe that the measure of labor productivity proposed above is the most appropriate in our context, given that the foreign labor productivity index used in our analysis also relies on total number of employees as input. Similar to the definition proposed for the effective real exchange rate, this variable is constructed by weighting the labor productivity of trading partners in relation to their import's share on the total imports of all sectors. Note that the construction of this index demands extensive information about the labor productivity of Brazilian import partners. Thus, in order to maximize the number of trading partners present in our sample, we decided to use the more conventional way of computing labor productivity, i.e., gross domestic product (GDP) per number of persons engaged.[5] The number of partners with available information about annual hours worked by persons engaged in Penn World Table database is considerably smaller than the number of partners with available information for the number of persons engaged.

Finally, real payroll index, also obtained from PIM-IBGE, served as a proxy for real wage and also for domestic income. This strategy is justified given that the evolution of wages in manufacturing sectors moves together with the general income of economy.

A detailed description of these variables is given below, where manufacturing sectors are indexed by *i* and years by *t*.

- $ip_{it} = \log(imports_{it}/(industrial\ production\ value_{it} + imports_{it} - exports_{it}))$.
- $\alpha_{it} = \log(industrial\ production\ value_{it}/total\ number\ of\ employees\ associated\ to\ production_{it})$.
- $E_{it} = \log(real\ exchange\ rate\ (R\$/LCU)_t \times the\ import's\ share\ of\ trading\ partners\ on\ the\ total\ imports_{it})$.
- $\alpha^*_{it} = \log(trade\ partners\ labor\ productivity_t \times the\ import's\ share\ of\ trading\ partners\ on\ the\ total\ imports_{it})$.

The descriptive statistics of these variables, reported in Table 2, reinforces the stylized facts about the relationship between import penetration, exchange rate and productivity. The average coefficient of import penetration in the period between 1996 and 2011 was 10.6%. Note, however, that its average growth rate was 7% per year reflecting a substantial increase of manufacturing imports participation on domestic consumption. It is a similar result when compared to the two large groups of sectors (consumption goods as well as intermediate and capital goods).

Otherwise, the average rate of the annual labor productivity did not strictly follow the import penetration performance. Considering all sectors, its growth rate was only 0.7% per year. For the sectors of consumption goods, the percentage is even lower, equal to 0.2%, whereas the group of intermediate and capital sectors had an annual growth rate of 1.1%.

Real effective exchange rate, on the other hand, had a distinct dynamic. As we may see, Brazilian currency strongly appreciated, in real terms, against the currencies of its trading partners. On average, the annual rate was −3.3% for all sectors. Considering only the group of consumption goods sectors this rate is even lower, reaching −4.8% per year.

Note that these facts are also compatible with the discussion presented in Section 2. The increase of import penetration seems to be related to the low performance of productivity in manufacturing sectors and the appreciation trajectory of the exchange rate.

On the other hand, additional aspects deserve attention and may also be important for explaining the advance of import penetration in domestic consumption. The index of foreign productivity indicates that the partners had a better performance in terms of labor productivity. In general, the annual average growth rate for all sectors was about 2.0%. Even when segmented by the two broad groups of sectors the performance per year continues to be practically the same.

Finally, it is seems that wages do not have a large influence on the recent diffusion of imports on domestic market. It is expected that real wage would have had an increase in this period impacting negatively the Brazilian manufacturing competitiveness favoring imports. However, the average growth rate of our proxy for real wage was near zero. In particular, for the group of intermediate and capital goods sectors, the annual rate was negative.

[5] GDP, measured by expenditure-side real at chained PPPs in US 2005 prices, as well as the number of person engaged are obtained from Penn World Table version 8.0.

Table 2
Descriptive statistics (1996–2011).

	ip_{it}	Δip_{it}	$\Delta\alpha_{it}$	ΔE_{it}	Δw_{it}	$\Delta\alpha^*_{it}$
All manufacturing industries – 17 sectors						
n	272	255	255	255	255	255
Mean	0.106	0.071	0.007	−0.033	0.001	0.022
Median	0.075	0.073	0.007	−0.036	0.002	0.020
Standard deviation	0.100	0.271	0.123	0.193	0.072	0.043
Min	0.001	−1.057	−0.420	−1.281	−0.410	−0.420
Max	0.434	1.298	0.492	0.452	0.254	0.268
Consumption goods industries – 7 sectors						
n	112	105	105	105	105	105
Mean	0.058	0.062	0.002	−0.048	0.005	0.024
Median	0.052	0.062	0.008	−0.035	0.005	0.023
Standard deviation	0.042	0.251	0.096	0.237	0.086	0.061
Min	0.001	−0.521	−0.269	−1.281	−0.410	−0.420
Max	0.219	1.049	0.263	0.452	0.254	0.268
Intermediate and capital goods industries – 10 sectors						
n	160	150	150	150	150	150
Mean	0.139	0.078	0.011	−0.022	−0.002	0.020
Median	0.101	0.081	0.007	−0.039	0.000	0.019
Standard deviation	0.114	0.284	0.138	0.154	0.060	0.024
Min	0.008	−1.057	−0.420	−0.518	−0.160	−0.056
Max	0.434	1.298	0.492	0.428	0.190	0.088

6. Empirical results

The restricted model described by Eq. (17) and the unrestricted model (18) are estimated by different methods. The estimation of (17) made use of four approaches in order to evaluate whether the results are influenced by the presence of some specific bias as discussed before: ordinary least squares (OLS), fixed effect (FE), GMM in differences (DIFF-GMM) proposed by Arellano and Bond (1991) as well as system GMM (SYS-GMM) proposed by Arellano and Bover (1995) and Blundell and Bond (1998). After that, the method of minimum distance is applied to estimate the structural elasticities in (18) using the coefficients obtained from the unrestricted models.

Table 3 presents the estimation results of the four approaches. In the first part of the table, we present the estimation of unrestricted models coefficients considering 17 sectors. We estimate a total of twelve models. All models include year dummies to control for time effects. The first two columns present the estimates obtained by OLS and FE. In the next columns, we report the coefficients estimated by GMM. The difference between them lies basically in the number of system equations and the composition of instrumental variables.

In the case of the models reported in columns 3–7, it is assumed that the real effective exchange rate and the foreign labor productivity index are exogenous, i.e., there is no sequence of lag instruments related to these variables in the first difference equation as well as in the equation in levels when the SYS-GMM is considered.

However, the construction of these two variables, as discussed earlier, involves measures that may be correlated to the others variables. The exogeneity of trading partner's exchange rate and their labor productivity that are used for constructing the variables is less controversial, especially because we are dealing with a level of analysis based on manufacturing sectors. Thus, we expect that sector shocks on Brazilian import penetration do not contemporaneously influence the partner's exchanges rates and labor productivity. However, in spite of this fact, these two variables also depends on the trading partners import's participation on total sector imports that may lead to simultaneity bias. For this reason, the models in columns 8–12 consider all variables in the system as endogenous.

Furthermore, the composition of instruments is also changed according to the sequence of lags. It may influence the validity of instruments as reported by Sargan test of over-identifying restriction, shown in the second part of Table 3. In the DIFF-GMM models of the columns 4 and 8, we impose a structure of lags inferior to $t-3$ in the equation in

Table 3
Unrestricted and restricted models estimates – all sectors.

	Dependent variable: ip_{it}		E_{it} and α^*_{it} as exogenous instruments					E_{it} and α^*_{it} as endogenous instruments				
	OLS	FE	DIFF-GMM ($t-2$)	DIFF-GMM ($t-3$)	SYS-GMM ($t-2$)	SYS-GMM ($t-2$)	SYS-GMM ($t-2$)	DIFF-GMM ($t-2$)	DIFF-GMM ($t-3$)	SYS-GMM ($t-2$)	SYS-GMM ($t-2$)	SYS-GMM ($t-2$)
α_{it}	−0.840***	−0.947***	−0.880***	−0.806***	−0.733***	−0.767***	−0.817***	−0.868***	−0.816***	−0.754***	−0.782***	−0.819***
	(0.135)	(0.134)	(0.164)	(0.174)	(0.124)	(0.127)	(0.139)	(0.151)	(0.165)	(0.126)	(0.132)	(0.118)
α_{it-1}	0.851***	0.734***	0.538***	0.478***	0.742***	0.752***	0.805***	0.552***	0.438**	0.758***	0.766***	0.797***
	(0.138)	(0.136)	(0.156)	(0.176)	(0.112)	(0.111)	(0.125)	(0.136)	(0.173)	(0.115)	(0.113)	(0.100)
E_{it}	−0.272***	−0.252*	−0.285**	−0.274**	−0.292***	−0.267***	−0.239**	−0.286***	−0.297***	−0.263***	−0.260**	−0.306**
	(0.094)	(0.121)	(0.102)	(0.098)	(0.092)	(0.100)	(0.097)	(0.117)	(0.106)	(0.100)	(0.112)	(0.119)
E_{it-1}	0.126	−0.073	−0.054	0.015	0.190	0.225	0.160	−0.071	0.139	0.171	0.179	0.001
	(0.232)	(0.439)	(0.472)	(0.487)	(0.415)	(0.395)	(0.430)	(0.423)	(0.348)	(0.393)	(0.370)	(0.386)
w_{it}	0.483**	0.574*	0.578	0.585	0.662*	0.533*	0.546*	0.534*	0.637**	0.566*	0.521*	0.563*
	(0.221)	(0.288)	(0.320)	(0.345)	(0.379)	(0.311)	(0.299)	(0.272)	(0.320)	(0.325)	(0.288)	(0.304)
w_{it-1}	−0.479**	−0.265	0.033	−0.007	−0.646***	−0.468**	−0.493**	0.027	0.048	−0.590***	−0.482***	−0.526***
	(0.222)	(0.311)	(0.260)	(0.252)	(0.223)	(0.231)	(0.214)	(0.242)	(0.257)	(0.181)	(0.185)	(0.196)
α^*_{it}	1.451***	1.566***	1.279***	1.247***	1.525***	1.424***	1.337***	1.252***	1.137**	1.254***	1.278***	1.011***
	(0.524)	(0.354)	(0.319)	(0.332)	(0.357)	(0.378)	(0.371)	(0.354)	(0.516)	(0.209)	(0.262)	(0.174)
α^*_{it-1}	−1.430**	−0.984	−0.840**	−0.812*	−1.518***	−1.441***	−1.354***	−0.747	−0.887*	−1.197***	−1.265***	−0.991***
	(0.576)	(0.642)	(0.549)	(0.482)	(0.582)	(0.540)	(0.494)	(0.518)	(0.532)	(0.421)	(0.448)	(0.279)
ip_{it-1}	1.001***	0.800***	0.724***	0.704***	0.994***	0.998***	0.986***	0.735***	0.696***	0.995***	0.998***	0.983***
	(0.012)	(0.043)	(0.050)	(0.066)	(0.023)	(0.019)	(0.026)	(0.046)	(0.063)	(0.024)	(0.017)	(0.022)
n	255	255	238	238	255	255	255	238	238	255	255	255
Instruments			197	181	241	240	239	208	192	274	273	271
Sargan statistic			216.694	194.183	251.793	245.986	234.068	217.713	202.960	275.886	265.084	262.772
p-Value (Sargan)			0.015	0.027	0.058	0.086	0.190	0.050	0.038	0.135	0.245	0.248
p-Value (Diff-Sargan)					0.635	0.831	1.000			0.743	0.951	0.957
p-Value ($AR(1)$)			0.023	0.018	0.017	0.021	0.021	0.023	0.018	0.019	0.021	0.023
p-Value ($AR(2)$)			0.142	0.134	0.127	0.145	0.140	0.147	0.147	0.127	0.148	0.143
β_α	−0.866***	−0.902***	−0.793***	−0.703***	−0.782***	−0.805***	−0.849***	−0.779***	−0.707***	-0.783***	−0.796***	−0.707***
	(0.130)	(0.104)	(0.109)	(0.126)	(0.105)	(0.101)	(0.107)	(0.103)	(0.113)	(0.113)	(0.101)	(0.088)
β_E	−0.219***	−0.321***	−0.381***	−0.344***	−0.248***	−0.229***	−0.226***	−0.403***	−0.364***	−0.213***	−0.203***	−0.311***
	(0.075)	(0.077)	(0.081)	(0.084)	(0.053)	(0.038)	(0.037)	(0.093)	(0.086)	(0.039)	(0.038)	(0.043)
β_w	0.419***	0.640***	0.414***	0.449***	0.528***	0.429***	0.510***	0.405***	0.352***	0.621***	0.357***	0.660***
	(0.206)	(0.181)	(0.163)	(0.146)	(0.170)	(0.153)	(0.112)	(0.161)	(0.177)	(0.139)	(0.103)	(0.119)
β_{α^*}	1.761***	1.746***	1.312***	1.280***	1.093***	1.573***	1.444***	1.280***	0.860***	1.424***	1.430***	1.120***
	(0.471)	(0.246)	(0.295)	(0.307)	(0.191)	(0.210)	(0.248)	(0.311)	(0.392)	(0.135)	(0.185)	(0.155)
δ	0.986***	0.789***	0.740***	0.708***	0.974***	0.984***	0.983***	0.737***	0.712***	0.982***	0.982***	0.986***
	(0.005)	(0.026)	(0.027)	(0.037)	(0.004)	(0.004)	(0.006)	(0.026)	(0.032)	(0.005)	(0.004)	(0.007)
p-Value (COMFAC)	0.220	0.862	0.640	0.727	0.136	0.554	0.891	0.526	0.767	0.255	0.391	0.281
p-Value $H_0: \beta_\alpha = \beta_E$	0.000	0.000	0.013	0.072	0.000	0.000	0.000	0.029	0.057	0.000	0.000	0.001

Notes:
(i) DIFF-GMM indicates that the models are GMM in differences and SYS-GMM indicates that models are system GMM.
(ii) The models in columns 3 and 8 include $t-2$ and earlier lags as instruments and models in columns 4 and 9 include as instruments $t-3$ and earlier lags.
(iii) The models in columns 5 and 10 include $t-2$ and earlier lags as instruments in equation in differences and $t-1$ as instruments in the equation in level.
(iv) The models in columns 6 and 11 include $t-2$ and earlier lags as instruments in equation in differences and $t-1$ as instruments in the equation in level, with exception of labor productivity variables where we consider $t-2$ as instrument in equation in levels.
(v) The models in columns 7 and 12 include $t-2$ and earlier lags as instruments in equation in differences and $t-1$ as instruments in the equation in level, with exception of labor productivity, real payroll index, foreign labor productivity index, variables where we consider $t-2$ as instrument in equation in levels.
(vi) Significant at *10%, **5%, ***1%.

first difference. Taking into account SYS-GMM, we do not change the sequence of instruments in the first difference equation, imposing lags dated $t-2$ and earlier. However, in the level equation, the lags of endogenous variables are changed according to the results of validity tests.

In this context, the estimation of all unrestricted models reveals firstly that there is no problem of residual serial correlation in lag 2. The null hypothesis is rejected at 10% level as well as estimated values of δ are significant at conventional levels validating the assumption that import penetration shocks may be described by an autoregressive process.

However, Sargan tests indicate that there is poor evidence that instruments are valid in DIFF-GMM models even when the composite of instruments is dated to $t-3$ and earlier. The null hypothesis that instruments are valid is in general rejected. In addition, our results also suggest that these instruments are weak.

According to Bond (2002) an estimated lag coefficient of dependent variable in DIFF-GMM models close to the same coefficient estimated by FE is evidence that instruments are highly persistence or close to random walk processes. As discussed in Section 4, this may generate downward bias on the estimator.

On the other hand, SYS-GMM exploits additional moment conditions by using lagged first differences as instruments for the equations in levels. As a result, the autoregressive coefficient of dependent variable is higher and lies between FE and OLS estimator as predicted by Bond (2002). In general, OLS estimator leads to an upward bias on the autoregressive coefficient of dependent variable due to the presence of sector-specific effect.

Additionally, in a situation where series may be modeled by a pure random walk, i.e., series with unit root process, Bond et al. (2005) highlighted that there is no correlation between endogenous variable and lagged levels of these series that are used as instruments. Different from the case where the series are highly persistent and therefore lagged instruments are considered weak, when the series have a unit root the instruments will not provide any information on the associated parameter of interest. As a consequence, for example, the autoregressive coefficient of dependent variable is not identified. On the other hand, system GMM estimator remains valid when extra moment conditions contains $t-2$ lagged instruments.

We test the unit root hypothesis by following Levin et al. (2002) approach without deterministic terms. Table A1 in Appendix A provides p-values of unit root test results for all series considered in our analysis.

According to the results we strongly reject the null hypothesis of unit root for the series of import penetration and effective exchange rate. On the other hand the series for labor productivity, real payroll index and foreign labor productivity index may be modeled by a unit root process. As a consequence, the lagged instruments related to these variables do not influence directly their associated coefficient of the unrestricted model in special difference GMM estimates being necessary to add extra lagged instruments available in the system GMM models.

This is the case of regressions in columns 6 and 11 where the lags of labor productivity instruments in level equation are changed from $t-1$ to $t-2$. Regressions in columns 7 and 12 also present a structure of $t-2$ lagged instruments for real payroll index and foreign labor productivity index in equation in levels.

Generally, SYS-GMM estimations improve the power of Sargan tests especially when we impose $t-2$ as the lag of first difference instruments in level equation for some variables. Only in the regressions reported in columns 7, 10, 11 and 12 of Table 3 we find evidence that instruments are valid given a p-value greater than 0.1. Furthermore, the difference Sargan test also reveals the importance of the additional structure of instruments present in SYS-GMM models. In all regressions we do not reject the null hypothesis that extra instruments are valid.

In light of this aspects unrestricted model estimated by SYS-GMM appear to be reasonable, especially in the case where E_{it} and y^*_{it} are assumed to be endogenous. This may be explained by the presence of simultaneous correlation between import penetration variable and trading partners import's participation on total sector imports used as a weight in E_{it} and y^*_{it} construction.

Despite the fact that the SYS-GMM models presented in the last two columns of Table 3 are preferred to the models in columns 6 and 7, this difference does not impact decisively the general results of the restricted model. As opposed to the unrestricted models, the restricted models are estimated by minimum distance method as proposed by Bond (2002). All the coefficients have the same sign and they are in accordance with theoretical model results. Only the coefficients associated to the labor productivity, real exchange rate and the proxy for real wage change, but not by a large expressive magnitude. Furthermore, according to COMFAC test, presented in the end of Table 3, the restrictions imposed by minimum distance estimation are easily accepted especially for the model in column 11.

Most important, the assumption made on E_{it} and y^*_{it} do not influence our conclusion about the impact of exchange rate and labor productivity on import penetration. When we conduct the test of equality of coefficients, in all cases we reject the null hypothesis that the estimated coefficient of labor productivity and real exchange rate are the same given a significance level of 0.01 as we observe the p-values in the bottom of Table 3.

Thus, as predicted by the micro-model, the impact of domestic labor productivity on import penetration is negative and superior to exchange rate. Considering only the SYS-GMM models, the value of productivity coefficient is at least two times larger than that of the exchange rate coefficient. It is the preliminary evidence supported by the micro-model.

Some additional aspects of results deserve attention. Our real wage proxy estimator is significant and as expected has a positive impact on import penetration. In absolute terms, its impact is also superior to real exchange rate. More interesting is the fact that the index of foreign labor productivity has the highest impact on the import penetration. Generally, the estimated elasticity is superior to unity while domestic labor productivity has a value near to 0.8. Considering the models in the last two columns, the ratio between domestic and foreign labor productivity elasticity is around 0.86 and 0.58, respectively, a representative percentage.

Our argument that foreign inputs matters to explain why exchange rate is less important than labor productivity lies in the fact that the participation of intermediate and capital goods in the domestic market is inelastic to effective exchange rate of the sector. At the moment that national manufacturing industry is deeply dependent of some foreign goods for producing, it is less likely that changes in the exchange rate may affect their consumption in domestic market. It seems the case of intermediate and capital sectors.

Table 4 presents the model estimation for this group that includes 10 sectors. We impose the exact same structure of lags for instrumental variables presented in the all sectors regression shown previously.

Our estimated models related to these group have also evidenced that lagged instruments are weak in first difference equation on the method of GMM in differences given that coefficient of dependent variable is near to the fixed effect coefficient. On the other hand, Sargan tests indicate that over-identifying restrictions are valid for all GMM models. Additionally, difference Sargan test also reveals that additional moment condition used in system GMM is accepted at 10% level.

All these aspects reveal that system GMM again yields preferable estimates. However, different from all sectors estimates, the composition of instruments may change considerably the results of restricted models. Notice that the validity of the restrictions imposed by minimum distance estimation is conditioned to it. Basically the only model that accepts the restriction is the model in column 6. In that case, we assume that E_{it} and y^*_{it} are exogenous variables.

Even if we consider the last model described in column 11 where the structure of lags is identical to the model in column 6, but all variables are considered endogenous, there are no substantial changes on the mainly results. The domestic productivity impact is significant and negative. The estimated coefficient of the foreign productivity index is positive and significant at 10% level and again has the largest impact among variables. The unique difference is related to the proxy of wage coefficient that is not significant in the model described in column 6.

Minimum difference estimators reported in columns 7 and 12 on the other hand present different results. In both cases real exchange rate coefficients are significantly different from zero and its impact is positive considering the regression of the last column. However, according to COMFAC test we strongly reject again the validity of the imposed restriction.

The relevant aspect is the fact that although exchange rate impact is negative as expected, its coefficient is not significant at 10% level for most regressions especially that reported in column 6. This results shows that import penetration of intermediate and capital good sectors is not sensitive to the exchange rate. This explains why, when we consider all manufacturing sectors, exchange rate has a limited impact on import penetration coefficient when compared to the labor productivity.

Notice that although the fact that the impact of exchange rate is inelastic for this group of sectors, this is an important empirical finding and suggests that the presence of imported inputs may explain this aspect, but it does not confirm that the second order effect of the theoretical model is valid. The confirmation that imported input is relevant for explaining the difference between labor productivity and exchange rate impacts demands that, additionally, the exchange rate elasticity have to be conditioned to some measure of the imported inputs ratio on total inputs used in these sectors.

In empirical terms it means that we also should incorporate to the model a variable of interaction between exchange rate and an imported input ratio measure. It is expected that the coefficient of these interaction will be positive, i.e., as long as imported input ratio increases it necessarily reduces the impact of exchange rate on the import penetration.

Table 4
Unrestricted and restricted models estimates – intermediate and capital good sectors.

	Dependent variable: ip_{it}		E_{it} and α^*_{it} as exogenous instruments					E_{it} and α^*_{it} as endogenous instruments				
	OLS	FE	DIFF-GMM ($t-2$)	DIFF-GMM ($t-3$)	SYS-GMM ($t-2$)	SYS-GMM ($t-2$)	SYS-GMM ($t-2$)	DIFF-GMM ($t-2$)	DIFF-GMM ($t-3$)	SYS-GMM ($t-2$)	SYS-GMM ($t-2$)	SYS-GMM ($t-2$)
α_{it}	−0.852***	−1.091***	−1.090***	−1.112***	−0.802***	−0.826***	−0.872***	−1.114***	−1.032***	−0.790***	−0.791***	−0.846***
	(0.174)	(0.169)	(0.151)	(0.160)	(0.205)	(0.227)	(0.220)	(0.156)	(0.182)	(0.230)	(0.234)	(0.186)
α_{it-1}	0.885***	0.337	0.348	0.264	0.811***	0.812***	0.846***	0.276	0.117	0.804***	0.802***	0.889***
	(0.181)	(0.279)	(0.234)	(0.230)	(0.215)	(0.215)	(0.196)	(0.248)	(0.293)	(0.237)	(0.237)	(0.192)
E_{it}	−0.143	−0.135	−0.136	−0.205	−0.167	−0.173	−0.090	−0.262	−0.317	−0.178	−0.233	−0.101
	(0.376)	(0.380)	(0.325)	(0.374)	(0.393)	(0.443)	(0.383)	(0.407)	(0.423)	(0.463)	(0.499)	(0.485)
E_{it-1}	0.671	0.718	0.703	0.554	0.754	0.710	0.758	0.627	0.421	0.568	0.616	0.414
	(0.532)	(0.727)	(0.659)	(0.574)	(0.724)	(0.779)	(0.763)	(0.613)	(0.615)	(0.771)	(0.756)	(0.715)
w_{it}	0.371	0.486	0.528	0.595	0.43	0.450	0.598	0.451	0.521	0.528	0.457	0.471
	(0.316)	(0.322)	(0.356)	(0.407)	(0.492)	(0.399)	(0.365)	(0.292)	(0.370)	(0.422)	(0.373)	(0.326)
w_{it-1}	−0.316	0.014	0.040	0.142	−0.492	−0.405	−0.348	0.284	0.301	−0.403	−0.389	−0.280
	(0.371)	(0.454)	(0.425)	(0.439)	(0.489)	(0.475)	(0.527)	(0.370)	(0.351)	(0.447)	(0.431)	(0.361)
α^*_{it}	1.975	2.318	2.294	1.856	2.179	2.147	1.874	1.767	0.863	1.842	1.922	1.463
	(1.353)	(1.755)	(1.548)	(1.688)	(1.651)	(1.788)	(1.944)	(1.556)	(1.978)	(1.851)	(1.714)	(1.981)
α^*_{it-1}	−2.085	−2.801	−2.778	−2.726	−2.161	−2.208	−2.134	−2.432	−2.094	−2.018	−2.034	−1.726
	(1.425)	(2.492)	(2.155)	(2.264)	(1.682)	(1.730)	(1.733)	(2.199)	(2.056)	(1.793)	(1.651)	(1.863)
ip_{it-1}	0.965***	0.622***	0.628***	0.604***	0.918***	0.932***	0.951***	0.600***	0.579***	0.934***	0.933***	0.961***
	(0.020)	(0.103)	(0.090)	(0.103)	(0.021)	(0.024)	(0.028)	(0.104)	(0.118)	(0.023)	(0.026)	(0.014)
n	150	150	140	140	150	150	150	140	140	150	150	150
Instruments			129	120	173	172	171	129	120	195	194	192
Sargan statistic			112.2	108.08	130.77	129.5	117.12	108.886	104.583	146.490	143.690	156.60
p-Value (Sargan)			0.322	0.208	0.869	0.874	0.971	0.404	0.282	0.921	0.937	0.744
p-Value (Diff-Sargan)					1.000	1.000	1.000			0.998	0.999	0.924
p-Value ($AR(1)$)			0.043	0.041	0.054	0.06	0.063	0.04	0.032	0.061	0.061	0.068
p-Value ($AR(2)$)			0.166	0.162	0.153	0.167	0.164	0.188	0.144	0.146	0.165	0.165
β_α	−0.663***	−0.857***	−0.810***	−0.741***	−0.783***	−0.948***	−1.057***	−0.808***	−0.507***	−0.983***	−0.585***	−1.446***
	(0.134)	(0.106)	(0.092)	(0.080)	(0.088)	(0.104)	(0.089)	(0.081)	(0.097)	(0.107)	(0.122)	(0.084)
β_E	0.041	0.042	0.233	0.230	−0.061	−0.100	−0.469***	0.233	−0.562***	1.324***	−0.382	2.147***
	(0.351)	(0.147)	(0.168)	(0.186)	(0.328)	(0.302)	(0.146)	(0.177)	(0.137)	(0.322)	(0.409)	(0.251)
β_w	0.265	0.051	−0.116	0.040	0.206	0.332	0.013	0.168	0.602***	−0.623***	0.787***	−1.502***
	(0.302)	(0.162)	(0.153)	(0.150)	(0.214)	(0.215)	(0.169)	(0.164)	(0.216)	(0.245)	(0.250)	(0.154)
β_{α^*}	1.696***	1.682***	1.862***	1.554***	1.919***	1.417***	1.173***	1.495***	0.895***	2.454***	1.828***	3.707***
	(0.501)	(0.523)	(0.470)	(0.408)	(0.375)	(0.201)	(0.282)	(0.388)	(0.383)	(0.219)	(0.224)	(0.158)
δ	0.980***	0.870***	0.888***	0.861***	0.961***	0.955***	0.953***	0.864***	0.839***	0.951***	0.992***	0.963***
	(0.012)	(0.059)	(0.054)	(0.040)	(0.007)	(0.006)	(0.009)	(0.044)	(0.039)	(0.007)	(0.010)	(0.007)
p-Value (COMFAC)	0.267	0.000	0.000	0.014	0.060	0.110	0.000	0.025	0.000	0.000	0.000	0.000
p-Value $H_0: \beta_\alpha = \beta_E$	0.068	0.000	0.000	0.000	0.071	0.035	0.009	0.000	0.737	0.000	0.698	0.000

Notes:
(i) DIFF-GMM indicates that the models are GMM in differences and SYS-GMM indicates that models are system GMM.
(ii) The models in columns 3 and 8 include $t-2$ and earlier lags as instruments and models in columns 4 and 9 include as instruments $t-3$ and earlier lags.
(iii) The models in columns 5 and 10 include $t-2$ and earlier lags as instruments in equation in differences and $t-1$ as instruments in the equation in level.
(iv) The models in columns 6 and 11 include $t-2$ and earlier lags as instruments in equation in differences and $t-1$ as instruments in the equation in level, with exception of labor productivity variables where we consider $t-2$ as instrument in equation in levels.
(v) The models in columns 7 and 12 include $t-2$ and earlier lags as instruments in equation in differences and $t-1$ as instruments in the equation in level, with exception of labor productivity, real payroll index, foreign labor productivity index, variables where we consider $t-2$ as instrument in equation in levels.
(vi) Significant at *10%, **5%, ***1%.

Table 5
Restricted models estimates – interaction between exchange rate and imported input ratio.

	E_{it} and α^*_{it} as exogenous instruments			E_{it} and α^*_{it} as endogenous instruments		
	Input imported ratio by sector – ϕ_i					
	Freitas et al. (2012)	Martinez (2015)	Guilhoto and Sesso Filho (2010)	Freitas et al. (2012)	Martinez (2015)	Guilhoto and Sesso Filho (2010)
n	255	255	255	255	255	255
Instruments	244	244	244	288	288	288
Sargan statistic	241.89	242.09	244.64	263.41	263.16	272.69
p-Value (Sargan)	0.138	0.136	0.113	0.481	0.486	0.328
p-Value (Diff-Sargan)	0.993	0.993	0.992	0.993	0.994	0.964
p-Value ($AR(1)$)	0.024	0.024	0.021	0.025	0.025	0.021
p-Value ($AR(2)$)	0.167	0.166	0.154	0.161	0.160	0.146
β_α	−0.619***	−0.619***	−0.600***	−0.799***	−0.800***	−0.826***
	(0.113)	(0.113)	(0.110)	(0.114)	(0.114)	(0.112)
β_E	−0.378***	−0.374***	−0.390***	−0.386***	−0.390***	−0.415***
	(0.037)	(0.039)	(0.059)	(0.043)	(0.043)	(0.063)
$\beta_{E\times\phi}$	1.280**	1.252***	2.571***	2.152***	2.188***	3.230***
	(0.519)	(0.510)	(0.798)	(0.491)	(0.489)	(0.918)
β_w	0.468***	0.463***	0.209	0.398***	0.391***	0.316**
	(0.164)	(0.162)	(0.155)	(0.140)	(0.139)	(0.130)
β_{α^*}	1.807***	1.782***	1.518***	1.232***	1.230***	1.148***
	(0.200)	(0.198)	(0.184)	(0.104)	(0.101)	(0.116)
δ	0.996***	0.996***	0.996***	0.979***	0.979***	0.978***
	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.004)
p-Value (COMFAC)	0.001	0.001	0.000	0.225	0.190	0.021
p-Value $H_0 : \beta_\alpha = \beta_E + \beta_{E\times\phi}$	0.011	0.011	0.001	0.000	0.000	0.000

(i) All models are estimated by SYS-GMM.
(ii) All models include $t-2$ and earlier lags as instruments in equation in differences and $t-1$ as instruments in the equation in level with exception of labor productivity variable as well as the interaction between exchange rate variable and imported input ratio where we consider $t-2$ as instrument in equation in levels.
(iii) The test evaluates the null hypothesis considering the sample mean value for ϕ.
(iv) Significant at *10%, **5%, ***1%.

Table 5 presents only the results of the restricted models[6] and include in its specification the interaction between effective real exchange rate variable and the ratio between the total value of imported input and the value of total inputs (domestic and imported) used in the production by the sector as a whole obtained by input–output matrices data estimated by three different sources: Freitas et al. (2012), Guilhoto and Sesso Filho (2010) and Martinez (2015). All authors estimate the input–output matrices for the period between 2000 and 2009 for several sectors including those treated here. Only the matrices of 2000 and 2005 are official and provided by IBGE. The imported input ratio ϕ_i therefore is computed as the average of the available ratios meaning that it is fixed along the years and varies according to the sector [7].

According to the tests of adequacy associated to unrestricted models in Table 5 we may not find further problems related to serial correlation as well as problems related to the validity of instruments. Again, SYS-GMM demonstrated

[6] To save space the estimated coefficients of unrestricted model that are estimated by SYS-GMM is not shown in Table 5. We also do not report estimated models where the structure of lagged instruments in SYS-GMM do not yield imposed restrictions validity in minimum distance regression.

[7] Our option for using a fixed imported input ratio based on the average ratios of the period among 2000 and 2009 is explained by the fact that there is no input–output matrix estimation for 2010 and 2011. Furthermore, despite the fact that Guilhoto and Sesso Filho (2010) have estimated input–output matrix for the first 4 years (1996–1999), they just only cover 13 sectors. Given these aspects, we have preferred to proxied imported input ratio by a fixed value along all the period in analysis than lose precious information related to the sectors and time.

being the preferable model given that the p-values of Diff-Sargan tests reveal that the hypothesis of additional set of instruments is not rejected.

In general, the addition of the variable of interaction do not change considerably the impacts of other variables especially the difference in elasticity between domestic labor productivity and exchange rate. Otherwise, the models estimated by data from Guilhoto and Sesso Filho (2010) tend to overestimate the coefficient of interaction as shown in columns 3 and 6 as well as to make the real wage coefficient insignificant in the former model. Nevertheless, the COMFAC test reveals that the imposed restriction is not valid for these models as well as for all models that consider exchange rate and foreign labor productivity as exogenous variables.

On the other hand, COMFAC tests also reveal that imposed restriction is accepted for models that consider exchange rate and foreign labor productivity as endogenous and make use of input–output matrices database from Freitas et al. (2012) and Martinez (2015). It is interesting to note that the results are practically identical between the two models.

That said, through the results of Table 5 it is possible to confirm our preliminary hypothesis that the reduced elasticity of exchange rate on import penetration is related to the participation of imported input on the total inputs used in the final production of the sector. As expected, the coefficient of the interaction between effective real exchange rate and input imported ratio by sector ($\beta_{E\times\phi}$) is positive and significant for all models. This means that a higher level of imported inputs ratio in a specific sector ϕ implies that exchange rate is less sensitive to import penetration given that as ϕ increases $\beta_{E\times\phi}$ also increases reducing the general impact of exchange rate on import penetration β_E.

For instance, the sectors of consumption goods, on average, has an imported input ratio of about 0.08 meaning that the elasticity of exchange rate is near to -0.21 considering models in column 4 and 5. On the other hand, the group of intermediate and capital good sectors has a ratio of 0.16. As a consequence, the elasticity of exchange rate is near zero, equal to -0.04, a much smaller value than the group of consumption goods. This finding is in line with the results of Table 4 where the elasticity of exchange rate is small and statistically non-significant. In fact, the level of imported inputs ratio matters for explaining the differential of elasticities.

In accordance with the results of Table 3, the hypothesis that coefficient of labor productivity are equal to the exchange rate is also rejected for all regressions considering the sample mean value for ϕ.

Notice that when the imported inputs ratio is null, the influence of exchange rate on penetration coefficient is still lower than the impact of labor productivity. Considering again the model in column 4, even when the imported inputs ratio is zero the elasticity of exchange rate is -0.386 against -0.799 from labor productivity, i.e., the values differs.

Note that these results do not necessarily contradict the predictions of our theoretical model[8]. It simply shows that there could exists other factors that influence the sensitiveness of exchange rate on import penetration other than the participation of imported input in total input used in the final production. In any case, we confirm that the presence of imported inputs on production influence the impact of the exchange rate and most relevant in substantial way.

Thus, what is important here is that our empirical findings are in accordance with the mainly results of the micro model that is independent of initial conditions, i.e., the signs of all estimated elasticities is coherent with the theory and that imported input ratio matters for explaining the differential of impacts between exchange rate and labor productivity.

7. Final considerations and policy analysis

According to our empirical findings labor productivity has been more important than exchange rate for explaining import penetration in the recent years. This aspect confirms the view supported by Bonelli and Pessoa (2010) and Ferreira and Fragelli (2011) that the recent progress of imports on Brazilian domestic market is broadly related to the productivity. As we presented before, labor productivity elasticities are considerably superior to the elasticity of exchange rate. The effect of domestic labor productivity on import penetration is at least two times larger than the exchange rate, a huge difference. Foreign labor productivity, on the other hand, has the largest influence indicating that there are other aspects that helps to explain the presence of imported goods on domestic market that do not depend on national economic policies.

[8] It is important to point out that although theoretical model predicts that those elasticities have the same magnitude, it depends on the functional form that we initially assume.

Table 6
Policy evaluation different scenarios.

	Import penetration (/100)			Labor productivity (% p.y.)		Exchange rate (% p.y.)		
	Mean	SD	Final value	Mean	SD	Mean	SD	Final value (in level)
Actual import penetration (1996–2003)	0.088	0.019	0.110	0.5	4.2	8.3	17.2	1.9
Actual import penetration (2004–2011)	0.123	0.009	0.148	1.4	8.7	−10.9	8.7	0.7
Scenario 1 (2004–2011)	0.096	0.012	0.084	2.5	0.0	0.0	0.0	0.0
Scenario 2 (2004–2011)	0.110	0.008	0.111	0.0	0.0	−2.5	0.0	0.4
Scenario 3 (2004–2011)	0.110	0.009	0.066	4.5	0.0	−10.9	8.7	0.7
Scenario 4 (2004–2011)	0.110	0.013	0.066	1.4	8.7	−4.0	0.0	1.3
Scenario 5 (2004–2011)	0.088	0.012	0.079	11.2	0.0	−10.9	8.7	0.7
Scenario 6 (2004–2011)	0.088	0.018	0.111	1.4	8.7	8.3	0.0	3.6

Note: SD standard deviation of simulations.

Most important is that the differential of impacts is a consequence of the inelasticity of exchange rate to the coefficient of imports from intermediate and capital goods sectors. This inelasticity is supported by the fact that intermediate and capital goods sectors group have a higher level of imported inputs in the final production. Our results revealed that exchange rate elasticity is lower the higher is the participation of imports in the total inputs of the sector.

The consequences of the reduced exchange rate effectiveness may be observed when we make a simulation exercise based on the estimated coefficients from unrestricted model described in the column 11 of Table 3. These estimated coefficients have been chosen given that it is the SYS-GMM estimation considering all variables endogenous that have good instrumental adequacy in accordance with the Sargan test as well as have the best result of COMFAC test.

We have simulated trajectories of productivity and exchange rate that is required to generate different import penetration scenarios considering the period after 2003. As we said before this is a distinct period and deserves attention because exchange rate suffered an intense process of appreciation of about 62%. Associated to this, Brazilian manufacturing labor productivity had a poor performance. A combination of huge appreciation with poor productivity performance promoted a massive increase of imports on domestic market.

Scenario 1 consists of forecasts of average levels of import penetration for 2004–2011 considering a constant annual growth rate for labor productivity of 2.5% and of 0% for exchange rate. Scenario 2 is the opposite, i.e., a constant annual growth of 0% for labor productivity and 2.5% for exchange rate. In all scenarios we made use of the observed wage and foreign labor productivity indexes series for the period as well as the estimated fixed effect. The statistics of the simulations are shown in Table 6.

As expected, when we impose the same annual growth rate for both variables considering scenarios where the opposite variable is fixed during all the period, the average level of import penetration is lower when domestic labor productivity has a positive and constant growth. In this hypothetical scenario the difference in terms of average levels of import penetration is about 1.4% and 2.7% in terms of final value.

On the other hand, it is also interesting to calibrate the labor productivity or exchange rate path that is necessary to reach some specific average level of import penetration. This is an important feature in terms of policy. In other words, given that policymakers have two variables of policy it should find out which is more efficient for reducing the participation of manufacturing imports on domestic market. This is the case we consider for the next scenarios.

Scenarios 3 and 4 assume respectively that labor productivity as well as exchange rate have a constant annual growth rate that is enough to generate an average level of import penetration compatible with a 2003 value, i.e., a mean of 0.11 (a target of 11% in the import penetration index) for the period between 2004 and 2011. It means a reduction superior to 1 percentage point in the actual import penetration average level of 0.123. In the case of Scenario 3 where no restriction on the exchange rate growth rate is imposed we show that it is necessary that labor productivity has a constant growth of 4.5% per year. When we execute the same exercise considering now only exchange rate as the policy variable it is necessary an annual appreciation rate of 4.0% per year to achieve the 2003 imports participation target as we observe in the results of scenario 4.

Imposing more constrained scenarios, i.e., an average level target of 1996–2003 in import penetration (8.8 percentage points), the labor productivity growth should have been 11.2% per year according to Scenario 5 whereas exchange rate should have had an appreciation rate of 8.3% each year as observed in Scenario 6.

Notice that different from Scenarios 3 and 4 the last two scenarios are not feasible in terms of policy. It is very difficult to promote policies that yield a labor productivity growth of about 11.2% per year. This is also true and more complicated in the case exchange rate. During the period of analysis we saw a huge appreciation of the Brazilian real exchange rate.

In this case, not only should the government need to engender a real exchange rate devaluation but with a magnitude of about 90 percentage points if we consider the final value of 2011 against the 2003 value. This policy, therefore, would have perverse consequences for the whole economy. A huge reduction on import penetration would in this case have demanded non-feasible policies related to labor productivity or exchange rate.

There are other aspects that explain the invasion of imports on Brazilian domestic market as we said before, for instance foreign labor productivity and fixed effects of sectors which are not manageable in terms of policy. The average growth of foreign labor productivity was 3.3% per year among 2004–2011. For instance, whether instead the foreign labor productivity have had a growth of 0% per year, the average level of Brazilian import penetration would have been almost 2 percentage points lower.

8. Conclusion

This paper evaluated the influence of Brazilian labor productivity and exchange rate on the participation of imports on the domestic consumption of manufacturing sectors measured by import penetration. We evidenced empirically that the importance of labor productivity is large to that of the real exchange rate. Furthermore, as predicted by our theoretical model, differences of impacts may also be explained by the presence of foreign inputs in the Brazilian manufacturing production. As long as the sector has a higher participation of imported input on the total of inputs used in production lower is influence of exchange rate on the import penetration is reduced.

The import penetration of the sectors of intermediate and capital goods is a special case given that the group is inelastic to the real exchange rate. As we pointed out, these sectors have the largest participation of foreign input in domestic production when compared to the sectors of consumption goods.

In light of our empirical findings it is possible to conclude that economic policies based on real devaluation influence the level of import penetration in a moderate way when compared to a policy of increasing domestic labor productivity. This conclusion challenges the view that the principal problem faced by Brazilian manufacturing industry was the appreciation of national currency (real) in relation to the others trade partner currencies. Furthermore, our results also confront the policy prescription for solving this problem.

It is sometimes recommended a discretionary policy of currency exchange rate devaluation until an optimum specific value. However, there are some drawbacks regarding this prescription. It is commonly accept that making a real devaluation by a discretionary increase of nominal exchange rate is not easy because of exchange rate pass-through to final prices. In other words, it is not easy make a real devaluation of a currency through nominal devaluation.

Secondly, an extension of our results indicates that for such economic policy to be effective it should focus especially on sectors with low imported input ratio which is extremely difficult. Otherwise, whether that policy also impacts the sectors associated to the group of intermediate and capital goods, the impact over import penetration is practically zero and may only affect their input costs. As a result, the elevation of the cost of capital goods could cause a decline in the level of investment on the economy.

Finally, not only are both labor productivity and exchange rate responsible for the massive increase of import penetration. Factors such as trade partner productivity and other fixed effect related to sectors are also import. In this sense, some policy target could be not feasible as for example reaching again the average level of import penetration of the period 1996–2003 as we demonstrated previously.

Appendix A.

Table A1
Unit root test (p-values).

Deterministic terms	ip_{it}	a_{it}	E_{it}	w_{it}	a^*_{it}
Individual intercept and trend	0.0000	0.2512	0.0000	0.0000	0.8158

Note: p-Values of Levin et al. (2002) unit root test.

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